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hostile? if a flag of truce, it has never been regarded. How much this little mammal has to do in sustaining the faunal balance in the east! To how many forms of life is it a food supply—to the creeping reptiles, the raptures of the birds, the rapacia of beasts, and even all-rapacious man. "Behold, therefore, the goodness and severity of God." Such is the rectitude of existence that whether beast or man, "no one liveth to himself, and no man dieth to himself."

"The whole temporal show related royally,
And built up to eterne significance,
Through the open arms of God."

But why tempt the depths? So here endeth this memoir of "little cotton tail."

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THE PALÆOZOIC ALLIES OF NEBALIA.

BY A. S. PACKARD, JR.

HAVING studied the anatomy and development of *Nebalia*, we are prepared to compare it with a group of fossil forms which are scattered through the older Palæozoic rocks from the lowest Silurian to the Carboniferous. In a brief article¹ Mr. Salter, nearly twenty years since, sketched out the characters and showed the relationship of *Ceratiocaris* and a number of allied forms to *Nebalia* in the following paragraph:

"Before the structure of *Ceratiocaris* was known, of which genus a reduced figure is here given, the rostral portion of *Peltocaris* could not have been understood. But a reference to the accompanying series of wood-cuts² will show that a tolerably broad rostrum, placed in the same relative position, occurs in *Ceratiocaris*. In the recent *Nebalia* it is fixed, and in *Dithyrocaris* and other genera it is perhaps yet to be discovered. Again, *Ceratiocaris*, together with its movable rostrum, has a bivalved shell, yet habitually keeps its valves half closed, as I learn from perfect specimens."

Salter then enumerates the characteristics of the fossil genera, beginning with *Hymenocaris*, which he considers the more generalized type, and in the wood-cuts, which we partly here produce, shows the geological succession of these genera, which also serves as a genealogical table. He regards them as *Phyllopod*s, associating with them *Estheria* and *Apus*, regarding the latter as

¹ On *Peltocaris*, a new genus of Silurian Crustacea, by J. W. Salter, Quarterly Journal of the Geological Society of London, Vol. XIX, 1863, p. 87.

² Our Fig. 1.

“the most complete and decided form, and it is one of the latest of the group, as it commences in the Trias.” He also says: “The links between these coal-measure forms and those of recent times,

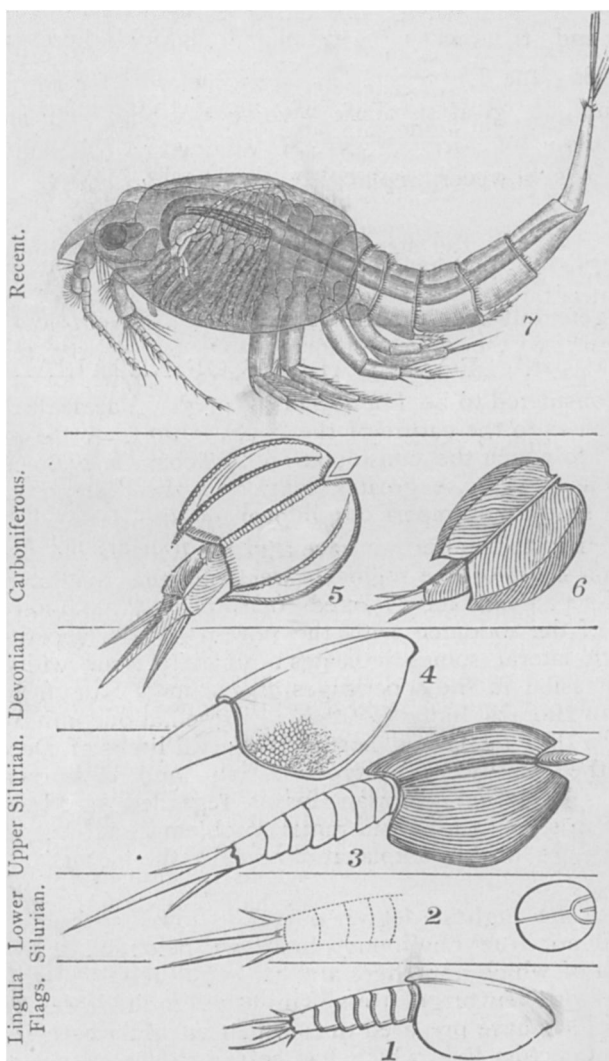


FIG. 1.—*Hymenocaris* (Lingula Flags). FIG. 2.—*Peltocaris* (Lower Silurian). FIG. 3.—*Ceratiocaris* (Upper Silurian). FIG. 4.—*Dictyocaris* (Devonian). FIG. 5.—*Dithyrocaris* (Carboniferous). (FIG. 6.—*Argus*.) FIG. 7.—*Nebalia* (recent).

are many of them wanting; but in *Nebalia* we have a good representative of the compact, shield-shaped form of *Ceratiocaris* the two valves soldered into one, and the rostrum attached, the

eyes being still beneath the carapace." It is evident from this that Mr. Salter regarded the fossil genera he enumerates as allied to and as the ancestors of *Nebalia*, and as representatives of it in Palæozoic times. He evidently adopted the views of Milne-Edwards and others as to the Phyllopodous nature of *Nebalia*.

Discarding the Phyllopod forms, we here reproduce Salter's figures and geological succession, which has been confirmed by the discoveries of Barrande and H. Woodward. Salter's figure of *Nebalia* is, however, replaced by an original one of *Nebalia bipes*.

In his article on the structure and systematic position of *Nebalia*,¹ Claus thus refers to the Palæozoic forms:

"It is generally considered that the oldest Palæozoic Crustacean remains whose shells and form of the body partly resemble *Apus* and partly show a great similarity to *Nebalia*, for this reason are considered to be Phyllopods, though we are without any information as to the nature of the limbs. But now the instructive error, to which the consideration of *Nebalia* gave occasion, will lead us to exercise greater caution in the interpretation of such incomplete and imperfectly known remains.

"In *Ceratiocaris* Salter, we have a great *Nebalia*-like carapace by which a series of free segments were covered, and moreover a long well-separated, lancet-formed rostrum. On the other hand, the form of the abdomen, with the powerfully developed telson beset with lateral spines, indicates a different form, which also finds expression in the appendages of *C. papilio* Salt., figured as antennæ or thoracic limbs. If these representations indicate true limbs, then they remind us most of the larval limbs of Decapods. So also the position of *Dictyocaris* Salt., and *Dithyrocaris* of Scouler to the other Silurian fossils regarded as Phyllopods (*Hymenocaris*, *Peltocaris*) will remain problematical until we have obtained more precise explanations as to the nature of their limbs.

"It is in the highest degree probable, however, that all these forms are not true Phyllopods, but have belonged to a type of Crustacea of which now there are no living representatives, but which, taking their origin from forms allied to the lower types of Entomostraca, have prepared the way for the Malacostracan type. Such a connecting link, which has served to the present day, we evidently find in the genus *Nebalia*."

In 1879,² without knowing the views of Claus, just quoted, we

¹ Siebold u. Kölliker's Zeitschrift, xxii, 1872, p. 329.

² The Nebeliad Crustacea as types of a new order. By A. S. Packard, Jr. AMERICAN NATURALIST, February, 1879, Vol. xiii, p. 128.

published a brief notice of the leading characteristics of the

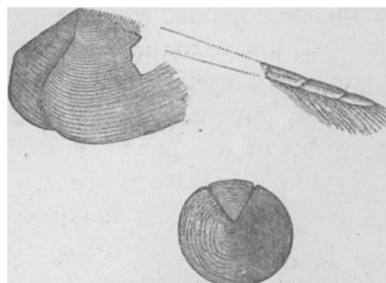


FIG. 8.—*Discinocaris bruceana*, natural size; side view and disk with the wedge-shaped rostrum in situ. After Woodward.

group, and proposed that the Palæozoic fossil forms, *Ceratiocaris*, etc., be united with the *Nebaliadæ* to form a separate order of Crustacea under the name of *Phyllocarida*.

Of the fossil forms, *Hymenocaris* was regarded by Salter as "the more generalized type."

The genera *Peltocaris* and *Discinocaris* characterize the Lower

Silurian period, *Ceratiocaris* the Upper, *Dictyocaris* the Upper Silurian and the lowest Devonian strata, *Dictyocaris* and *Argus* the Carboniferous period.

On examining the figures of Salter and of Barrande, for we have been unable to study any of the fossils themselves, owing to their extreme rarity, the relationship to *Nebalia* is very marked, as seen in the form of the carapace, the nearly free or detached rostrum, unless the separation took place after the death of the animal, and also of the rather long, slender abdomen. Upon examining the appendages at the end of the abdomen there is to be seen an important distinction from *Nebalia*; a long, slender telson is usually present, with a single pair of large caudal stylets, or cercopoda, in form like those of *Nebalia*. But in *Hymenocaris* and *Peltocaris* the telson appears to be represented by a pair of small (in *Peltocaris* minute) spines. In the presence of the telson in the typical fossil genus *Ceratiocaris*, we certainly have an important character separating the type with its allies from *Nebalia*, and allying them to the Decapods; and thus in the provisional synopsis of the order presented in the memoir soon to be published in Hayden's Report, we have placed the fossil forms in a separate sub-order from the *Nebaliadæ*.

While the posterior edges of the abdominal segments in *Hymenocaris* appear to be spined as in *Nebalia*, there are some characteristics of importance in the fossil forms which deserve mention; these are the sculptured carapace, especially of *Dictyocaris*, in which the surface is reticulated.¹ Moreover the size of these

¹ It should here be remarked, that while the carapace of *Nebalia* is smooth, upon making a section of it a reticulated structure is plainly seen in the parenchyma or soft parts of the shell, but it is entirely too minute to be perceptible in the shell even

genera was enormous, but if we, as we seem to be warranted in doing, regard *Nebalia* as a survivor and decrepid or old-age type of the order, which has lost the ornamentation of the integument, the size and the telson even being dwarfed, smooth-skinned, and in general very simple compared with the forms which existed at the time when the type culminated and before it began to die out, we may have an explanation of the greater simplicity of the carapace and abdomen of *Nebalia*, as compared with its Palæozoic ancestors.

From our total lack of any knowledge of the nature of the limbs of the fossil Phyllocarida, we have to be guided solely by analogy, often an uncertain and delusive guide. But in the absence of any evidence to the contrary,² there is every reason to suppose that the appendages of the head, thorax and abdomen were on the type of *Nebalia*, since there is such a close correspondence in the form of the carapace, rostrum and abdomen.

But whatever may be the differences between the fossil forms represented by *Ceratiocaris*, etc., they certainly seem to approach *Nebalia* much nearer than any other known type of Crustacea; they do not belong to the Decapods; they present a vague and general resemblance to the zoëa or larva of the Decapods, but no zoëa has a telson, though one is developed in a postzoëal stage; they do not belong to any other Malacostracous type, nor do they belong to any existing Entomostracous type, using those terms in the old sense. No naturalist or palæontologist has referred them with certainty to the Decapods, or to any other Crustacean type than the Phyllopods. To this type (in the opinion of Metschnikoff and Claus, who have studied them most closely) under high powers. This structure may be comparable with that of *Dictyocaris*, especially as Salter remarks (*Ann. and Mag. Nat. Hist.*, 1866, p. 161): "The entire surface of the carapace is marked with hexagonal reticulations one-thirtieth of a line in diameter, of which the areæ are convex and the bounding lines sunk on the exterior aspect. This would, I think, indicate the ornament to be connected with the structure of the carapace rather than to be a mere external sculpturing. As no films can be obtained thick enough to furnish a section for microscopic examination, the point cannot be ascertained."

² Close scrutiny of specimens in existence may yet show indications as to the nature of the limbs; for example, Salter figures, in the *Annals and Magazine of Natural History*, 3d series, Vol. v, 1860, p. 154, Fig. 3e, what he calls the jaws of *Ceratiocaris papilio*, but the figure appears to us rather to represent a four jointed piece of an antenna. In Fig. 2 there are represented the tergal portion of seven segments lying under the carapace. If fresh attention were directed to the discovery of the nature of the limbs, success might result.

they certainly do not belong; and thus, reasoning by exclusion, they either belong to the group of which *Nebalia* is a type, or they are members of a lost, extinct group. The natural conclusion, in the light of our present knowledge, is, that they are members of the group represented by the existing *Nebalia*.

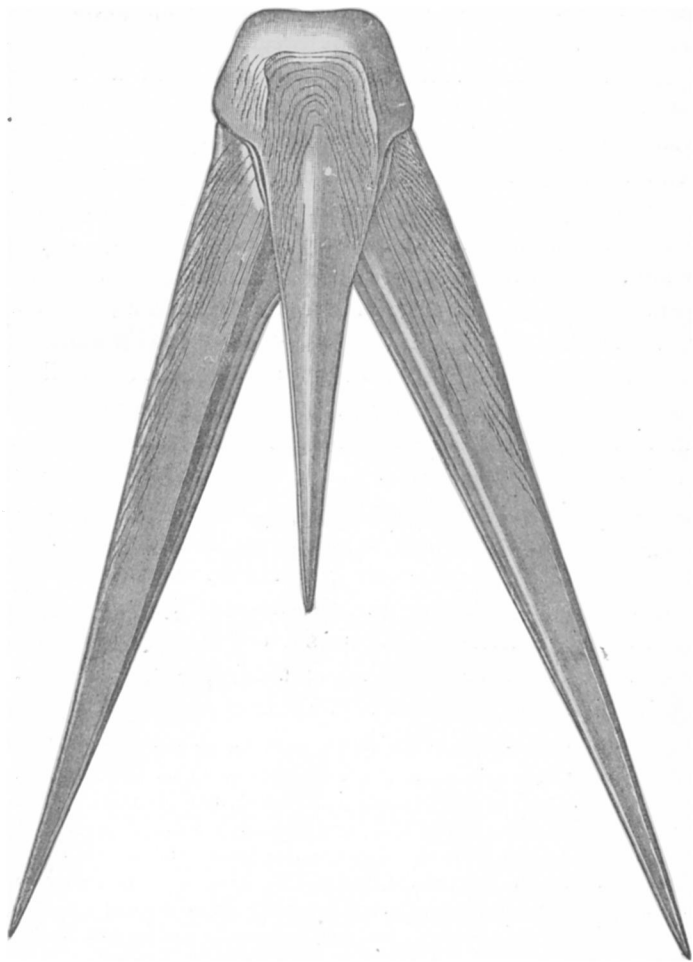


FIG. 9.—*Dithyrocaris neptuni* Hall; telson and cercopoda, natural size. From Hall.

In order, then, to summarize our present knowledge of the living *Nebalia* and its fossil allies, we will give what we regard as the characters of the group, which may be regarded as provisional, though perhaps of some present use.

External diagnostic characters of the order Phyllocarida.—Body

compressed; consisting of twenty-one segments—five cephalic, eight thoracic and eight abdominal. Carapace compressed, with, no regular hinge, loosely attached to the body by an adductor muscle; with a movable rostrum inserted in a depression in the front edge, the carapace covering the basal joints of the abdomen. One pair of stalked eyes; no simple eyes. Two pairs of well-developed, many-jointed, long, large antennæ, the first pair biramous, the second pair with a very long flagellum in the male. Mandibles weak, with a remarkably long three-jointed palpus. Two pairs of maxillæ; the first with a remarkably long, slender, multiarticulate exopodite; second pair well developed, biramous; no maxillipedes; eight pairs of biramous, broad, thin, respiratory, thoracic feet, not adapted for walking; the exopodites divided into a gill and flabellum; four pairs of large and two pairs of small abdominal swimming feet; no appendages on the seventh segment, the terminal one bearing two long caudal appendages (cercopoda). No telson present in the living species; well developed in the Ceratiocaridæ. Young developed in a brood sac; development direct; no marked metamorphosis; the young but slightly differing from the adult.

Remarks.—By the sum of the foregoing characters the Phyllocarida appear to be excluded from any other group of Neocaridan Crustacea.

The differential characters separating them from the Decapods or any other Malacostracous type, are:

1. The loosely-attached carapace, the two halves connected by an adductor muscle.
2. The movable rostrum, loosely attached to the carapace.
3. The very long and large mandibular palpus; the long, slender appendage of the first maxillæ, and the very long biramous maxillæ.
4. The absence of any maxillipedes.
5. The eight pairs of pseudophyllopod thoracic feet, not adapted for walking; the animal swimming on its back.
7. No zoëa-formed larva.

The differential characters from the Phyllopods are the following:

1. Carapace not hinged; a rostrum present.
2. Two pairs of well-developed long and large multiarticulate antennæ; the hinder pair in the male longer than the first pair.

3. The thorax and its appendages clearly differentiated from an abdomen.

Internal Organs.—No functional shell gland; no highly-developed liver tubes like those of all Phyllopods; stomach and cœcal appendages (liver) entirely unlike those of Phyllopods.

The nervous system is entirely unlike the Phyllopod type, and approaches more the Decapod and Tetradeapod type.

The resemblance to the Copepoda is in some points quite

striking; this is seen in the equal size of the two pairs of antennæ, in the form of the abdomen, and the two caudal appendages, as well as the spines on the hind edge of the seg-

ment, in the well-developed palpus of the mandibles, in the absence of maxillipedes, as well as the simple reproductive glands.

In short, we regard the Phyllocarida as an accelerated, prematurative type of Crustacea which became well established in the lowest Primordial period, flourishing at a time when there was no Malacostracous forms, and which culminated in the Upper Silurian period, and became nearly extinct at the close of the Carboniferous. Judging the group by the structure of *Nebalia* alone, whether we consider the external or the internal structure, it is a highly composite or

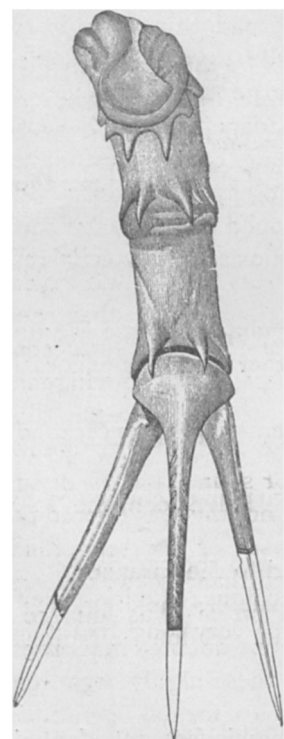


FIG. 12.—*Echinocaris punctatus*; abdomen, dorsal view, natural size. From Hall.

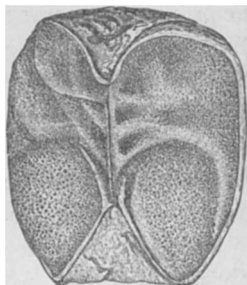


FIG. 10.—*Echinocaris multinodosus*.



FIG. 11.—*Echinocaris sublevis*.

synthetic type, combining Copepod, Phyllopod and Decapod-like features with more fundamental characteristic ones of its own. The group existed at a time when, save in the Carboniferous period, no Malacostraca, or at least very few, existed, and they thus anticipated the incoming of the more specialized Decapods.

Like many other synthetic, ancient types, the fossil representatives were of colossal size compared with the living survivors.

While some of the fossil forms were of moderate size, though very large compared with *Nebalia*, some must have been of gigantic proportions. For example, in *Dithyrocaris neptuni* Hall, of which Fig. 9 represents the telson and cercopoda of natural size, the entire animal must have been some two feet in length. The *Echinocaris punctatus* must have been nearly a foot in length, while the *Echinocarides* (Figs. 10 and 11), described recently by Mr. R. P. Whitfield, were considerably smaller.

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AMERICAN WORK ON RECENT MOLLUSCA IN 1881.

BY WILLIAM H. DALL.

(Continued from November number.)

Psychology.—Owing to the secluded life of most mollusks they are not easily subjected to long-continued observation, and perhaps for this reason notes on their affections or mental processes are nearly unknown. But that careful observation would reveal in many mollusks a much higher degree of intelligence than they are usually credited with, there can be little doubt. A small contribution to this subject is contained in the paper on "Intelligence in a Snail," by the writer (AM. NAT. Dec. 1881, pp. 976-7). The observations there noted indicate that some species of the genus *Helix* are capable of recognizing a call or sound, and of distinguishing it from other calls or sounds. Since this was printed the writer has had information of two other cases of the same kind, though the facts are less clearly indicated than in the one first mentioned. Dr. Lockwood's observations on *Mytilus* indicate a certain degree of intelligence, and it cannot be doubted that observations on cephalopods would show that these highly organized mollusks are capable of more or less complex mental operations.

Geographical Distribution and Catalogues.—In the Annals N. Y. Acad. Sci. (II, pp. 117-126) in an article "On the relations of the fauna and flora of Santa Cruz, W. I.," Bland shows, from a discussion of the land shells, that it is probable that St. Thomas and other islands of the Virgin group were formerly connected with Santa Cruz, but that in spite of a submarine ridge (with, however, 700 fathoms of water over its greatest depression) extending to Saba, there is no evidence of a dry-land connection of the latter